C-A Department

SUPPLEMENTAL ELECTRICAL SAFETY STANDARDS

Owner: C-AD Chief Electrical Engineer
Date: November 27, 2000

In general, the policies shown below are intended to augment the National Electric Code and OSHA standards where they do not address the design and operation of a research accelerator complex.

Index

1. **Power Connectors. The components listed in this section shall be UL approved or NEMA equivalent for standard AC power circuits up to 480 volts.**

1.1. 120 Volt Single-Phase Service

1.1.1. <u>Receptacles</u>

1.1.1.1. Duplex outlet. Straight blade receptacle. 2-pole, 3-wire w/ground. Brown melamine body with metal mounting "ears." For back and side wiring. Flush mounting. 20 ampere, 125 volt AC. BNL stock # I-31925.

1.1.1.2. Duplex outlet. Straight blade. 2-pole, 3-wire w/isolated ground, orange melamine body with metal mounting ears for back and side wiring. 20 ampere, 120 volt. BNL stock # I-31926.

1.2. 208 Volt, Three-Phase Service 30 Amp

1.2.1. <u>Receptacles</u>

1.2.1.1. Single outlet. Power lock. Three phase. For equipment grounding, 4-pole, 5-wire w/ground. 30 ampere, 600 volt AC, 20 ampere. Die-cast aluminum cover and steel shell. BNL stock # I-22494

1.2.2. <u>Plugs</u>

1.2.2.1. 4-pole, 5-wire plug. Polarized, grounded. 30 ampere, 600 volt AC, 20-ampere straight style. Fully armored. Painted blue. Cord grip. Accepts cable sizes from 0.625 in. to 1.000 in. o.d. for 3-phase 120/208 volt only. Nonmetallic housing. BNL stock # I-22432

1.2.3. <u>Cord Connectors</u>

1.2.3.1. Connector female, 5-wire, 600 volt, 30 ampere, with rubber cord grip, cable diameter 0.875 to 1.000 in., color blue. BNL stock # I-22434

1.3. 120 Volt, Single-Phase Service - 50 Amp

1.3.1. <u>Receptacles</u>

1.3.1.1. Twist lock, 50 ampere, 600 volt, 3-wire, grounded (grounding terminal untapped) - Cat. No. 7381, Harvey Hubble Inc.

1.3.2. <u>Plugs</u>

1.3.2.1. Male cap - 50 ampere, 600 volt, 3-wire, grounded to casting, cable size 0.437 to 1.062 in. o.d. - Cat. No. 7763, Harvey Hubble Inc.

1.3.3. Cord Connectors

1.3.4. Connector body - 50 ampere, 600 volt, 3-wire, grounded to casting - cable size 0.437 to 1.062 in. o.d. - Cat. No. 7762, Harvey Hubble Inc.

1.4. 480 Volt, Three-Phase Service

1.4.1. Receptacles

1.4.1.1. 4-pole, 3-wire cable plug. Style 2, 30 ampere, 250 volt DC, 600-volt AC, weather resistant, rain tight. Pressure terminals wire size #10 - #6. Protected contacts. For 3-phase 480 volt only. *

1.4.2. Plugs (Rubber Connectors)

1.4.2.1. 4-pole, 3-wire cable plug. Style 2, 30 ampere, 250 volts DC, 600 volts AC, weather resistant, rain tight. Accommodates 0.875 to 1.375 in. diameter cable. W/cable grip, rubber bushing, protected contacts and fastening ring. For 3-phase 480 volt only. Male. * BNL stock # I-22194

1.5. 480 Volt Three-Phase Service

1.5.1. Receptacles

1.5.1.1. 4-pole, 3-wire cable plug. Style 2, 60 ampere, 250 volt DC, 600-volt AC, weather resistant, rain tight. Pressure terminals wire size #6 - #2, protected contacts. For 3-phase 480 volt only. *

1.5.2. Plug (Rubber Cord Connectors)

1.5.2.1. 4-pole, 3-wire cable plug. Style 2, 60 ampere, 250 volt DC, 600-volt AC, weather resistant, rain tight. Accommodates 0.390 to 1.375 in. diameter cable. W/cable grip, rubber bushing, protected contacts and fastening ring. For 3-phase 480 volt only. *

* Special Use Only - Not For General Use - See Chief Electrical Engineer.

2. Polarity And Identification Marking - Electric Motors - Ground Fault Detection And Mitigation - Phase Arrangement - Control And Power Transformers - Security System Wiring

2.1. AC Power Marking

2.1.1. For single and multiple conductors intended for lighting and power mains, feeders, sub-feeders, and branch circuits, the individual conductors shall have their outer coverings taped or painted on natural finish in solid colors for polarity and identification purposes as follows:

2.1.2. For a grounding conductor, use Green or bare copper.

2.1.3. For 120 volt, single phase, use one Black for the "hot" conductor and one White or Natural Grey for the neutral.

2.1.4. For 208 volt, 3-phase, 4-wire, use Black for ØA, Red for ØB, Blue for ØC, White or Natural Grey for neutral. Use 3-pole breaker only.

2.1.5. For 120/208-volt single phase, use wire insulation color or tape to denote which two of the three "hot" phases are connected (Black for ØA, Red for ØB, Blue for ØC). Use white or natural gray for the neutral. These shall use only a 2-pole breaker for the supply.

2.1.6. For 480 volt, single-phase, use wire insulation color or tape to denote which two of the three phases are connected (Brown for ØA, Orange for ØB and Yellow for ØC).

2.1.7. For 480 volt, three-phase, phase shall be identified by the use of 3 black wires marked A, B, C or 1, 2, 3, or tape banded Brown for ØA, Orange for ØB and Yellow for ØC.

2.1.8. In all cases the white or natural gray colored conductors shall be used as the identified or neutral conductor.

2.2. DC Power Marking

2.2.1. When direct current and alternating current conductors are contained within the same raceway or enclosure, the DC cables, where practical, shall be identified by wire insulation color or tape as red (+) plus, black (-) minus. Additional identification consisting of one- half inch band of yellow tape, paint or similar marking shall be placed on all the direct current conductors at each distribution point, panel board or cut-out box.

2.3. Electric Motors

2.3.1. Motors greater than 5 HP, 3-phase, shall be wired to a 480 volt, 3-phase supply with overload protection.

2.3.2. Motor starter contactors shall be the non-reversing type.

2.3.3. AC magnetic line starters shall be 3-pole; 600 volt rated with a maximum 120-volt AC control coils.

2.4. Ground Fault Detection and Mitigation

2.4.1. Panel boards supplying 480 volts and ungrounded Delta connections shall have ground detection devices for each building service. Disabling of a ground-fault detection system requires approval by the C-AD Chief Electrical Engineer.

2.4.2. If a ground on a sub-station is detected, the C-A D Chief Electrical Engineer and other appropriate affected personnel shall be notified immediately. Actions to remediate the grounded conductor shall be addressed promptly.

2.5. Phase Arrangement

2.5.1. Phase arrangement shall be as outlined in NEC 384-3(F).

2.6. Control and Power Transformers

2.6.1. The three-phase neutral shall be grounded at the transformer only.

2.6.2. The single-phase terminal marked "X2" or equivalent shall be grounded at transformer only.

2.7. Security System Wiring

2.7.1. System wiring shall be protected from physical damage. Cable runs outside cable trays shall be in conduit. Alternatively, supervised circuits could be used to insure circuit integrity.

2.7.2. Safety related wiring shall be protected against unauthorized or inadvertent modification in a strict configuration management control-system. The cables in trays and the exteriors of conduits shall be distinctly labeled.

3. Flammability Requirements For Cables

3.1. Permanent Wiring

3.1.1. All field wiring within the buildings shall meet the requirement of ANSI/UL 1581 Vertical Tray Flame Test or IEEE 383, 70,000 BTU/hr Vertical Tray Flame Test. Cables installed in air ducts, plenums, and other spaces used for environmental air shall be plenum cables that pass the NFPA 262/UL 910 Fire and Smoke Test. Cables installed in vertical runs in a shaft shall be riser cables that pass the UL 1666 Riser Cable Flammability Test.

3.1.2. The BNL Electrical Safety Committee has pre-approved the use of tray rated cable types and applications. They are shown in Attachment 2. For large installations, other cables may be appropriate. Before purchase of signal and power cable, the C-AD Chief Electrical Engineer or his designate shall review the specifications. Cable that is not listed as compliant with the National Electric Code (NEC), but can be shown to meet the intent, is approved after review and concurrence by the designated representative of the Laboratory Electrical Safety Committee. When appropriate, flame and/or electrical tests may be performed to demonstrate compliance with the intent of the NEC. Flume/smoke tests will be conducted in cooperation with the BNL Fire Protection Engineer.

3.2. Temporary Electrical Power and Lighting Wiring (See NEC Article 305)

3.2.1. Temporary wiring for experiments, tests and development work shall be removed immediately upon completion of construction or purpose for which the wiring was installed. The power and lighting cable types shall be NM, S, SE, SEO, SJ, SJE, SJEO, SJO, SJOO, SJT, SJTO, SJTOO, SO, SOO, ST, STO or STOO. Temporary wiring shall be installed for no longer than one year.

3.3. Optical Fiber Cables

3.3.1. Optical fiber cables shall be permitted to be installed in cable trays. Type OFN or OFC shall be used for general-purpose application. (See NEC Article 770)

3.4. Coaxial and Multiconductor Cables for Data and Signal

3.4.1. Type CM general purpose communication cables shall be permitted to be installed in cable trays.

4. Protection Against Exposed High Current Electrical Bus

4.1. The following policy and procedures apply only to high current conductors associated with powering magnets, accelerator and/or beam line components, experimental apparatus, or such devices in test or conditioning areas. Such exposed conductors are generally referred to as "bus" or "bus bar."

4.2. It is the policy of the Collider-Accelerator Department that high current bus shall be insulated or have protective barriers in all areas except for those where Lockout/Tag out Requirements are applicable or for those areas where specific electrical interlock systems are employed. This section describes procedures for protecting personnel from the particular hazards of exposed high current bus.

4.3. For the purpose of this section, these definitions apply:

4.3.1. <u>High Current Bus</u> - any conductor powering magnets, accelerator and/or beam line components, experimental apparatus, or such devices in test or conditioning areas connected to a power source capable of delivering a current of 100 amperes or more.

4.3.2. <u>Free Access Area</u> - areas that are not locked or locked areas that do not have controlled access.

4.4. Design Criteria

4.4.1. Exposed high current bus shall be protected from accidental approach or contact by persons or objects.

4.4.2. In <u>free access areas</u>, protection shall be accomplished by providing physical barriers to approach and contact such as insulation, guards, covers, enclosures, screens, platforms, or other suitable physical protection.

4.4.3. In <u>controlled access areas</u> containing exposed high current bus, protection shall be accomplished by providing:

4.4.3.1. Physical barriers to approach and contact such as insulation, guards, covers, enclosures, screens, platforms, or other suitable physical protection, equivalent to that required for free access areas; or

4.4.3.2. Interlocked entrances where upon entrance to the area the interlock system shall de-energize the energy source for any exposed high current bus.

4.4.4. Except for "captive key" type interlocks, the presence of electrical interlocks do not reduce or replace the requirements of Lockout/Tag out Requirements when specific work is to be performed on the source of energy (power supply) feeding the bus or work on the bus or load(s) attached to the bus.

4.4.5. Removable covers, guards, etc., shall be labeled "Danger High Current." Posting shall be at approximately 20-foot intervals.

5. Low Voltage, High Current Power Distribution Systems: Power Source Over-Current Protection - Power Source To Single Load Conductors - Connection To Multiple Loads - Connection Of Source-To-Load Conductors - Selection Of Source-To-Load Conductors - Monitoring And Control Of High Power Modules

5.1. The distribution of current from a low voltage power source to one or more loads, though generally not considered to present a personal shock hazard, can present a significant hazard because of possible high current capability of the power source. In addition, high currents, coupled with lack of adequate over-current protection and/or undersized conductors, can lead to overheating of the conductors between source and load, thus presenting a fire hazard. The designer of such a system or systems shall be responsible to assure that good engineering practice is incorporated in the design.

5.2. The criteria presented here apply only to the protection of electrical conductors between a low voltage, high current power source, as defined hereafter, and one or more electrical loads; i.e., situations where power is distributed from a low voltage, high current source by ribbon cable.

5.3. These criteria do not apply to the protection of conductors <u>within</u> commercially manufactured electrical equipment that utilizes or requires one or more low voltage, high current power sources. Such equipment includes commercially manufactured standardized crate systems such as, but not limited to, FASTBUS, CAMAC, STD, VME, VXI, MULTIBUS I/II, and NIM. Additional conditions of said non-applicability are that the internal power distribution is enclosed and has not been modified. For those cases where the power source for such equipment is external, these criteria do apply, with the equipment being considered a single load. Additionally, when power is supplied to an external load from such equipment, these criteria do apply, with the equipment here being considered as the power source.

5.4. For the purpose of this section, these definitions shall apply:

5.4.1. <u>Low Voltage</u> - a voltage that is less than 10 volts AC (rms) or 50 volts DC.

5.4.2. <u>High Current Power Source</u> - a low voltage source, with a designed or rated output current greater than 10 amperes.

5.4.3. <u>Over-current Trip</u> - a condition for which current limiting or interruption actuate to limit or reduce the current from a power source to some pre-defined value; i.e., a fuse, circuit breaker, resistor, electronic current limit, or other suitable device.

5.4.4. Load - the electrical device or circuit, having resistive and/or reactive impedance that consumes electrical energy from the power source. A printed circuit board or module is generally considered a single load. However, crate systems, capable of powering one or more modules or printed circuit boards within a single chassis, are a special case. For such crate systems: the back plane, its conductors and connectors, and installed boards or modules are all to be considered as a single load to the power source. The power source conductors are considered to terminate at the point of back plane connection.

5.5. Power Source Over-current Protection

5.5.1. A low voltage, high current power source may or may not be internally over-current protected. The nature and level of protection shall be determined to properly specify the source-to-load conductors. Power sources may be internally or externally modified to provide a known safe level of over-current protection. The external addition of over-current protection shall be as close to the power source as possible.

5.6. Power Source to Single Load Conductors

5.6.1. The conductors supplying power to a single load shall be adequately terminated and sized to safely carry the load current under all anticipated load conditions. Occurrence of a short circuit at any point between the source and load, either between the supply conductors or between supply conductors and ground or common conductors, shall not lead to overheating or damage of the conductors or the insulation of the conductors. These criteria shall also apply to sense conductors, when present, between a source and load. Sense leads shall be protected from exposure to the full load capability of the supply by fuses or resistors.

5.7. Over-current Trips

5.7.1. For cases where a trip condition does occur, the source-to-load conductors shall safely support the fault current during the time interval necessary to cause the trip. If the threshold of the over-current trip condition is adjustable, the source-to-load conductors shall be designed and sized for the highest adjustable threshold.

5.7.2. For cases where the trip does not occur, the conductors shall be adequately sized to safely conduct the short circuit current.

5.8. Multiple Conductors

5.8.1. A particularly dangerous situation exists when conductors are wired in parallel to provide sufficient current carrying capability to the load as well as to reduce source-to-load conductor impedance. The failure of a single conductor may not produce a trip condition but may result in potentially unsafe current levels in the remaining parallel conductors. For such cases, each of the conductors between the source and load shall be protected against inadvertent over-currents at any point between the source and each individual load, and connections at both the source and load shall be sufficiently sized to prevent overheating, inadvertent disconnection, or failure. Special circumstances may require over-current protection on each of the conductors of any installation using parallel conductors.

5.9. Connection to Multiple Loads

5.9.1. Connection of a single low voltage, high current power source to multiple loads can result in hazardous conditions if due consideration is not given to the criteria delineated for single loads. Emphasis here is given to the protection of conductors between source and load, given the possibility of an over-current condition at any point in the power distribution system. The requirements for power source-to-single load conductors shall also apply for a multiple load configuration.

5.9.2. Installation of passive over-current protection devices, such as fuses and circuit breakers, between the source power bus and single load taps is often the most practical solution to the safe powering of multiple loads. Installation of such passive over-current protection devices can allow the safe utilization of conductors more appropriately sized to the individual load.

5.9.3. Printed circuit boards and modules, that are powered from a back plane that is supplied by one or more low voltage, high current power sources, are best protected as loads by the interior installation of fuses or other current limiting devices. Installation of such protection is highly recommended.

5.10. Connection of Source-to-Load Conductors

5.10.1. Dangerous situations often occur because of poor installation of current carrying conductors at the source or load. The design of cable and connectors shall resolve the possibility of ambiguity of polarity and voltage at the point of termination. All cables shall be properly identified. Use of keyed connectors and color-coding shall be employed to prevent reverse polarity and incorrect voltages in circuits. Mechanical connections shall be adequately tightened. Lock nuts, lock washers or Belleville washers shall be used where appropriate. Bolts, screws and other fastening devices shall not be used as current conductors unless specifically designed for such purposes. Special caution is advised when dissimilar metals are used for connection in high-current applications.

5.11. Selection of Source-to-Load Conductors

5.11.1. The selection of conductor size and type between source and load(s) is an engineering problem, which has no simple answer. The designer, following good engineering practice, should consider the over-current characteristics of the power source, conductor impedance, distance between source and load, connection/terminal impedance, ratings of the conductor insulation, the nature of conductor paths and raceways, ambient temperatures and component temperature ratings. Proper consideration of these and other applicable factors will assure the selection of a conductor type and size that will ensure safe operations.

5.11.2. When choosing conductors, the maximum load current shall be multiplied by a factor of 1.25, and the resulting value shall be used to determine the appropriate conductor size listed in Attachment 1. Refer to the NEC for configurations other than that shown at the top of the table in Attachment 1. Conductors connected to a power supply buss shall be fused with fuses sized at 0.8 of the ampacity value listed for the conductor in Attachment 1.

5.12. <u>Monitoring and Control of High Power Crates</u>

5.12.1. Every crate within a rack should be monitored as follows:

5.12.1.1. If forced-air cooled, output air temperature should be monitored, preferably in a few places, in order to check on uniformity.

5.12.1.2. Any heat exchangers should have the inlet and outlet temperature of the water monitored.

5.12.1.3. All power supplies to a crate should have their voltages and currents monitored. This permits a normal crate configuration to be compared to the actual. Should a deviation of about one module worth of current be detected, an alert should be generated. A greater deviation should cause an AC power trip. Similarly, this should be accomplished for the over- or under-voltage situation.

5.12.1.4. Unless the monitoring circuit has successfully completed a self-check, power to the load should be disabled.

5.12.1.5. A smoke detector is recommended. This needs to be carefully done, as most smoke detectors do not work in high airflow. If the rack airflow system is self-contained, which is highly recommended, implementation of an appropriate fire suppression system, triggered by the smoke detectors, shall be considered.

6. High Voltage Coaxial Connectors

6.1. This section identifies typical connectors used for several voltage ranges. In general, connectors for high voltage shall be chosen such that they are incompatible with connectors for signal cables. Only components properly rated for the intended application shall be used as shown below. Deviations shall be submitted to the Experimental Safety Review Committee for review.

6.2. Due to the physical compatibility with BNC connectors, which have a lower voltage rating, except for signal levels, the use of MHV or BNC connections is prohibited. Red-jacketed cable shall be used for high voltage applications unless specifically exempted by the Experimental Safety Review Committee.

6.3. Systems up to 5 kVDC

6.3.1. The standard coaxial cable connector for use with RG-59B/U shall be the Kings Electronics 1705-01 (plug) and 1702-1 (jack), or equivalent. BNL Stock #A-69852 (plug), A-69855 (jack).

6.3.2. The standard coaxial cable connector for use with RG 58C/U shall be the Kings Electronics 1705-2 or AMP 51426-1, or equivalent. BNL Stock #A-69852 (plug), A-69855 (jack).

6.3.3. Red jacketed RG-59B coaxial cable is BNL Stock #A-30304.

6.3.4. The standard coaxial panel connector for flange mount type should be either Kings 1707-1 or AMP 51421 and the standard panel connector for D hole-mount type should be either Kings 1704-1 or AMP 51494, or equivalent. BNL Stock #A-69853 (flanged bulkhead), A-69854 (Bulkhead type).

6.3.5. The bulkhead adapter for coaxial applications shall be King Electronics 1709-1 or AMP 225064, or equivalent. BNL Stock #A-69857 (bulkhead male/male).

6.4. Systems up to 10 kVDC

6.4.1. The standard cable connector shall be the Reynolds Industries P/N167-4535 or the Kings Electronics 1065-2 (for use with type C cable), or equivalent.

6.4.2. The standard coaxial panel connector shall be the Reynolds Industries P/N167-3555 or the Kings Electronics 1064, or equivalent.

6.4.3. The standard coaxial panel feed-through shall be the Reynolds Industries P/N167-3705, or equivalent.

6.5. Systems up to 20 kVDC

6.5.1. The standard coaxial cable connector shall be the Reynolds Industries P/N167-3516 (for use with RG 213/U), or equivalent.

6.5.2. The standard coaxial panel connector shall be the Reynolds Industries P/N167-3517, or equivalent.

6.5.3. A "D" hole shall be used for mounting all panel connectors except flange-mount type connectors.

6.5.4. Systems that require voltages above 20 kVDC shall utilize connectors rated for the maximum design voltage.

6.6. Open or Unmated Connectors

6.6.1. When it is possible to energize an unmated connector and create a shock hazard, connectors that fully protect accidental exposure to open contacts shall be used whenever possible. If no satisfactory connectors exist, then procedures and/or interlocks shall be utilized as specified in the C-A OPM. (Note: At the design stage, any energy stored in capacitor and cables shall be considered.)

7. Guidelines For Electrical Grounding Of Experimental Apparatus

7.1. The primary consideration of both AC and DC electrical grounding is to provide protection to personnel. Other grounding considerations for equipment protection or noise reduction shall not compromise the level of safety.

7.2. Specific Guidance

7.2.1. In cases where the NEC and/or IEEE Standard 1100-1992 does not provide adequate guidance for the design of specialized experimental components, the plan for grounding, related energy control and configuration management shall be provided to the Experiment Safety Committee for review. The plan shall also include test procedures to confirm the operational functionality.

7.2.2. In conjunction with Plant Engineering, the C-AD will provide an appropriate grounding grid as part of the conventional services in the experimental hall. Each experimental grounding plan shall be integrated within the overall grounding scheme.

7.2.3. All 480V transformers with ungrounded (3 wire) windings shall have ground fault detection.

7.2.4. It is recommended that experiments install supplemental ground fault detection on ungrounded power distribution to their apparatus.

7.2.5. All racks and equipment shall be AC grounded for safety in accordance with the NEC.

7.2.6. ES&H Standard 1.50 and 1.52 shall be incorporated into the design with respect to the maximum allowable voltage differential in a ground fault.

7.2.7. Specialized power outlets (“clean”, UPS, emergency, etc.) shall be clearly identified and labeled. Outlets with isolated grounds shall be clearly identified and labeled.

7.2.8. Each experiment shall designate a coordinator to assure compliance with the C-AD grounding requirements.

7.2.9. In addition to the review by the Experiment Safety Review Committee, grounding plans and associated changes shall be reviewed by the Chief Electrical Engineer.

7.2.10. Documentation shall include one-line diagrams of the grounding plan drawings. Any changes to the drawing shall be in accordance with the C-A OPM requirements.

Note: The table shown is for COPPER conductors.

Table 310-16. Ampacities of Insulated Conductors
Rated 0-2000 Volts, 60° to 90°C (140° to 194°F)
Not More Than Three Conductors in Raceway or Cable or Earth
(Directly Buried), Based on Ambient Temperature of 30°C (86°F)

Size	Temperature Rating of Conductors. See Table 310-13.			
	60°C (140°F)	75°C (167°F)	85°C (185°F)	90°C (194°F)
AWG kcmil	TYPES τTW, τUF	TYPES τFEPW, τRH, τRHW, τTHHW, τTHW, τTHWN, τXHHW, τUSE, τZW	TYPE V	TYPES TA, TBS, SA SIS, τFEP, τFEPB, τRHH, τTHHN, τTHHW, τXHHW
	COPPER 60°C	75°C	85°C	90°C
18	....	....	....	14
16	....	....	18	18
14	20τ	20τ	25	25τ
12	25τ	25τ	30	30τ
10	30	35τ	40	40τ
8	40	50	55	55
6	55	65	70	75
4	70	85	95	95
3	85	100	110	110
2	95	115	125	130
1	110	130	145	150
1/0	125	150	165	170
2/0	145	175	190	195
3/0	165	200	215	225
4/0	195	230	250	260
250	215	255	275	290
300	240	285	310	320
350	260	310	340	350
400	280	335	365	380
500	320	380	415	430

600	355	420	460	475
700	385	460	500	520
750	400	475	515	535
800	410	490	535	555
900	435	520	565	585
1000	455	545	590	615
1250	495	590	640	665
1500	520	625	680	705
1750	545	650	705	735
2000	560	665	725	750

AMPACITY CORRECTION FACTORS

Ambient Temp °C	For ambient temperatures other than 30°C (86°F), multiply the ampacities shown above by the appropriate factor shown below.				Ambient Temp °F
21-25	1.08	1.05	1.04	1.04	70-77
26-30	1.00	1.00	1.00	1.00	79-86
31-35	.91	.94	.95	.96	88-95
36-40	.82	.88	.90	.91	97-104
41-45	.71	.82	.85	.87	106-113
46-50	.58	.75	.80	.82	115-122
51-55	.41	.67	.74	.76	124-131
56-60	. . . .	.58	.67	.71	133-140
61-70	. . . .	.33	.52	.58	142-158
71-80	. . . .	. . . .	.30	.41	160-176

† Unless otherwise specifically permitted elsewhere in this Code, the overcurrent protection for conductor types marked with an obelisk (†) shall not exceed 15 amperes for 14 AWG, 20 amperes for 12 AWG, and 30 amperes for 10 AWG copper; or 15 amperes for 12 AWG and 25 amperes for 10 AWG aluminum and copper-clad aluminum after any correction factors for ambient temperature and number of conductors have been applied.

Cables Acceptable for Use in Cable Trays at BNL

	Power Cable			Control Cable	Signal Cable			Optical Fiber Cable
Conductor Type	Single Conductor		Multi-Conductor	Multi-Conductor	Coaxial[2]	Twisted Pair	Multi-Conductor	
Minimum Conductor Size	AWG 1/0 (Equipment Grounding Conductor: AWG 4)		AWG 18	AWG 24	AWG 20	AWG 24	AWG 24	
Acceptable Cable Types	*NEC Cable Types:* MI, AC, MC, Welding Cable	*The following when marked "for CT use":* THW, THHN, THWN, XHHW, RHW, RHH, and Diesel Locomotive Cable or Transit Cable	TC, NM, NMC, SNM, SE, USE, UF, PLTC, MV	TC, PLTC, CM, MP (But not CMX or MPX)	CM CL2[3], CL3[3], CATV, PLTC (But not CL2X, CL3X or CATVX)	CM, PLTC, MP (But not CMX or MPX)	TC, PLTC, CM, MP (But not CMX or MPX)	OFN or OFC OFNP OFNR OFCR OFCP
Standards	§	UL-44, UL-83 or AAR S-501	UL 1277 for TC Cables	UL 1277, UL 13 or UL 444	UL 444, UL 13	UL 444, UL 13	UL 1277, UL 444 or UL 13	
Insulation Material and Thickness	§	UL-44, UL-83	§	§	§	§	§	§
Other Standards		ICEA S-19-81 and ICEA S-66-524						
IEEE 383 Vertical Tray Flame Test[1]	§	•	§	§	§	§	§	§
Air Ducts and Plenums[4]	Only MI and	Not Permitted	Not	¶	¶	¶	¶	¶

Cables Acceptable for Use in Cable Trays at BNL

	Power Cable			Control Cable	Signal Cable			Optical Fiber Cable
Conductor Type	Single Conductor		Multi-Conductor	Multi-Conductor	Coaxial[2]	Twisted Pair	Multi-Conductor	
	MC		Permitted					
Vertical Runs in a Shaft[5]	NEC Art. 300-21	NEC Art. 300-21	NEC Art. 300-21	¶	¶	¶	¶	¶
In & Outdoor Wet and Dry	•	•	•	•	•	•	•	•
Underground Duct	¶	¶	¶	¶	¶	¶	¶	¶
Sunlight Resistance	¶	¶	§(PLTC) ¶	§(PLTC) ¶	§(PLTC) ¶	§(PLTC) ¶	§(PLTC) ¶	¶
Hazardous Locations	¶	¶	§(PLTC) ¶	§(PLTC) ¶	§(PLTC) ¶	§(PLTC) ¶	§(PLTC) ¶	
Oil Resistant	¶	¶	¶	¶	¶	¶	¶	¶
Others	¶	¶	¶	¶	¶	¶	¶	¶

§The specified cable above automatically meets this requirement.
•Cable must be specified to meet this requirement.
¶To be specified according to the specific application need.

THE BOLD AND UNDERLINED CABLE TYPES ARE WIDELY AVAILABLE AND RECOMMENDED.

NOTES: Observe the other requirements in National Electrical Code Article 318 and Chapter 8 Communication Systems.

The similar tests are:

ANSI/UL 1581-1160 Vertical Tray Flame Test
IEC 332-3 "Test on Bunched Wire or Cables"
CSA FT 4 Vertical Flame Test

For coaxial cables used on high voltage DC circuits, the outer braid conductor shall be at ground potential. The rated voltage of the coaxial cable shall be greater than or equal to the operating voltage or it shall be Hi-Pot (voltage withstanding test, AC or DC) tested for the equivalent voltage levels. The following table is some typical Hi-Pot test voltages.

Hi-Pot Test Voltage Shall Be Applied for a Minimum of One Minute.

Operating Voltage, VDC	Voltage Withstanding Test Voltage, VAC, +10%, -0%	Voltage Withstanding Test Voltage, VDC, +10%, -0%
2,200	5,560	7,900
4,000	7,650	10,800
5,000	10,000	14,200

Approval required, see appropriate authority having jurisdiction (AHJ).

Cables for this category are called *PLENUM* rated. See NEC Articles 300-21, 300-22 and other related articles for the installation of cables in plenum. *PLENUM*: A compartment or chamber to which one or more air ducts are connected and that forms part of the air distribution system.

Cables for this category are called *RISER* rated. See NEC Articles 300-21, 300-22 and other related articles for the installation of cables in riser. *RISER*: Cables installed in vertical runs and penetrating more than one floor, or cables installed in vertical runs in a shaft.

AAR Association of American Railroad
ICEA Insulated Cable Engineers Association
IEC International Electrotechnical Commission
IEEE Institute of Electrical and Electronics Engineers
NEC National Electrical Code
UL Underwriters Laboratories, Inc.